

“The Meteoritic Component in Impact Deposits” - Final Report

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1. Introduction – Proposed Research

This proposal requested support for a broad-based research program designed to understand the chemical and mineralogical record of accretion of extraterrestrial matter to the Earth. The primary goal of this research is to study the accretion history of the Earth, to understand how this accretion history reflects the long-term flux of comets, asteroids, and dust in the inner solar system and how this flux is related to the geological and biological history of the Earth. This goal is approached by seeking out the most significant projects that can be attacked utilizing the expertise of the PI and potential collaborators. The greatest expertise of the PI is the analysis of meteoritic components in terrestrial sediments. This proposal identifies three primary areas of research, involving impact events in the early Archean (3.2 Ga), the late Eocene (35 Ma) and the late Pliocene (2 Ma).

In the early Archean we investigate sediments that contain the oldest recorded impacts on Earth. These are thick spherule beds (Lowe et al., 1989), three of which were deposited within 20 m.y. If these are impact deposits the flux of objects to Earth at this time was much greater than predicted by current models. Earlier work used Cr isotopes to prove that one of these contain extraterrestrial matter, from a projectile with Cr isotopes similar to CV chondrites (Shukolyukov et al, 2000a). We planned to expand this work to other spherule beds and to search for additional evidence of other impact events. With samples from D. Lowe (Stanford Univ.) the PI proposed to screen samples for high Ir and Cr so that appropriate samples can be provided to A. Shukolyukov for Cr-isotopic analyses. This work was expected to provide evidence that at least one interval in the early Archean was a period of intense bombardment and to characterize the composition of objects accreted.

The late Eocene is also a period of intense bombardment with multiple spherule deposits and two large craters (e.g., Glass and Koeberl, 1999). Farley et al. (1998) demonstrated an increased ^3He flux to marine sediments that was attributed to an increase in interplanetary dust due to a shower of comets invading the inner solar system. We planned to detect a change in the Cr-isotopic composition in the flux of fine-grained extraterrestrial matter to ocean sediments. This would provide evidence for the comet shower hypothesis. We planned attempt to locate late Eocene impact deposits in a new high resolution, hi-latitude site that had the potential for excellent preservation and new information of the sources and effects of these impacts.

Although most impacts on Earth occur in deep-ocean basins, only one such event is known - the late Pliocene impact of the Eltanin asteroid. The ejecta from this impact includes Ir-rich impact melt, spherules, and actual meteorites from the km-sized mesosiderite asteroid. Through a study of the ejecta, we can learn about the formation, distribution, alteration and preservation of Ir-rich deposits. We can also learn about meteorite survival during hypervelocity impacts and we can study pieces of a km-sized object to learn more about the mesosiderite parent body. Analyses of sediment cores and geophysical exploration of the impact site can further our

understanding of the processes involved in deep-ocean impacts and potential effects on the terrestrial climate and biosphere. We planned analyses of this ejecta, a search for ejecta 5000 km distant from the impact area, and a new oceanographic expedition to study and sample the impact site.

In addition to these three specific areas of research, the PI planned to remain flexible and available to exploit new opportunities presented by new discoveries, and to engage in new collaborations if other researchers require his expertise to develop new projects that fit within the objectives of the overall research program.

2. Completed Research - Publications, and Research Accomplishments

Within the period of this grant, the PI published 11 papers, was guest editor for two special issues of journals (*Deep Sea Research*, *Astrobiology*), and contributed to 14 abstracts presented at scientific conferences and workshops. The PI participated in polar research expedition ANT XVIII/5a aboard the *FS Polarstern* in Spring 2001, to explore deposits of the deep-ocean impact of the Eltanin asteroid. The PI also organized a workshop on the subject of "Impacts and the Origin, Evolution, and Extinction of Life" held at UCLA on Feb 8 & 9, 2002 (<http://www.ess.ucla.edu/rubey/program.html>). Also, a considerable amount of data has been acquired, that will be used in publications over the next few years, supported by continued NASA funding of this project.

Our analyses of early Archean spherule beds confirmed a meteoritic component in three beds (S2, S3, and S4), all of which have anomalous Ir and Cr-isotopic compositions (Kyte et al., 2003). Details of the Ir analyses along with detailed descriptions and sample locations of the spherule beds are provided by Lowe et al. (2003). Samples of bed S1 studied have been found to contain very low Ir concentrations and we have not yet attempted isotopic analyses.

We identified the late Eocene microtektite and cpx-spherule layers in a new core from the South Atlantic (ODP Site 1090) using Ir analyses. This deposit was independently discovered by B.P. Glass and S. Liu (U. Delaware) and we announced this jointly at the Chicago Meteoritical Society meeting. Initial results of the Ir analyses are presented by Kyte (2001a). We are now collaborating with B.P. Glass and S. Liu, supplementing their microtektite work with chemical analyses, and we have found significant Ir anomalies associated with late Eocene deposits in two new sites from the S. Atlantic and W. Indian oceans. Only preliminary work has been performed on Cr-isotopic analyses on Eocene spherules. Our initial data have detected a meteoritic component, but these results will not be final until a number of samples have been analyzed, probably late in 2003.

The greatest progress was on the Eltanin asteroid impact (late Pliocene). Three research papers (Kyte, 2002a-c) appeared in a special volume of Deep Sea Research II on the topic of Ocean Impacts. The PI was a co-editor for this volume, which includes an introductory paper (Gersonde et al., 2002). This volume includes papers presented at a conference on this topic in Bremerhaven, Germany, in 1999. These papers are results of numerous analyses of bulk sediments, impact melt and meteorite debris from the late Pliocene (2.5 Ma) impact of the Eltanin asteroid into the Bellingshausen Sea (e.g., Gersonde et al., 1997). These results are the

culmination of several years work on sediment cores from an oceanographic expedition in 1995 to explore the Eltanin impact. Much of this work was performed under an earlier grant from NSF, but a significant portion of the effort, including NAA and microprobe analyses, as well as manuscript preparation was supported by NASA. We did not find evidence of this impact in sediments from the Antarctic Peninsula (Kyte, 2001b), but this was really a shot in the dark on poorly dated sediments that had little chance of success (and experimental costs were paid by a very small grant from the Ocean Drilling Program). We also did not find it in detailed analyses of several meters of high-resolution core from the S. Atlantic (unpublished data). We were a bit perplexed by this, but it now appears that the impact is older than previously estimated, and we sampled the wrong part of the core. A major part of this research effort took place on expedition ANT XVIII/5a of the research vessel *FS Polarstern*. From Feb 20 through April 14, 2001, the PI participated on this polar research expedition which included two weeks in the area of the Eltanin impact event. Only preliminary results are available so far. We have recovered meteorite-bearing impact deposits in as many as 17 sediment cores covering a region of 80,000 km² of the ocean floor. A map of the expedition track can be found at http://www.ess.ucla.edu/faculty/kyte/antarctic_map.jpg. To date, we have performed over 250 Ir analyses on samples from this expedition. Several hundred sediment samples were sieved and separated into sand and gravel size fractions by colleagues at the Alfred Wegener Institute, Bremerhaven, Germany. The PI has picked through a large portion of these, quantifying meteorite and melt rock abundances in the ejecta found in these sediments.

We also engaged in several interesting studies of KT boundary sediments. We are working with an Ocean Drilling Program scientific party to characterize the KT boundary in a new core from the Tasman Sea (unpublished data). We collaborated on the distribution of PGEs in several KT boundary sites (Lee et al., 2003). We tested the KT boundary soot hypothesis with new samples from the central N. Pacific (Wolbach et al., 2003). The PI also participated in a multidisciplinary conference on Catastrophes in Earth History, in Vienna, which was dubbed as the fourth in the "Snowbird" series of conferences. A paper in the proceedings volume (Kyte, 2002d) is a general review on tracers of extraterrestrial matter in sediments.

3. References

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Publications Resulting from NASA Grant NAG 5-9441, "The Meteoritic Component in Impact Deposits" Frank T. Kyte, PI

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A. Published Papers

1. Kyte F.T. (2001a) Identification of late Eocene impact deposits at ODP Site 1090. *In* Gersonde, R., Hodell, D.A., and Blum, P. (Eds.), Proc. ODP, Sci. Results, **177**, 1–9 [CD-ROM]. Available from Ocean Drilling Program, Texas A&M University, College Station TX 77845-9547, USA.
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11. Kyte F.T., Shukolyukov A., Lugmair G., Lowe D.R. and Byerly G.R. (2003) Early Archean spherule beds: Chromium isotopes confirm origin through multiple impacts of carbonaceous chondrite type projectiles. Geology **31**, 283-286.

B. Edited Journal Issues

1. *Ocean Impacts: Mechanisms and Environmental Perturbations* (2002) R. Gersonde, A. Deutsch, B. Ivanov, F.T. Kyte, guest editors, Deep Sea Research II, 49 no. 6, pp. 952-1169. **EDITED VOLUME**
2. *Impacts and the Origin, Evolution, and Extinction of Life* (2003) F.T. Kyte, guest editor, Proceedings of the 10th Rubey Colloquium, Astrobiology, 3 no. 1, 1-215. **EDITED VOLUME**

C. Abstracts

1. Liu S., Kyte F.T. and Glass B.P. (2000) Upper Eocene spherules at Ocean Drilling Program Site 1090B. Met. Plan. Sci. 35, A98-99.
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